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THE CALENDAR YEAR AS A TIME UNIT IN DROUGHT STATISTICS¹

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As almost everyone knows, the year is generally considered as being too long a unit for use in compiling drought statistics. While admitting the general soundness of that view, it is believed that the disadvantages of the calendar year have been somewhat exaggerated. The case of Arkansas in 1930, when the percentage of the normal precipitation received was 96 per cent, will naturally come to mind. In this case two of the months, January and May, had 223 and 200 per cent of the normal, respectively, and the real lack of rain that caused the failure of the cotton crop was confined to the months of June and July, with 22 and 19 per cent, respectively. Most persons fail to consider that the very great rainfall of January and May was in itself quite abnormal and not likely to again happen in the next 50 years.

The reason why a shorter period than the year has not heretofore been used in compiling drought statistics is most likely because of the overlapping of drought periods from one month to the next and the fact that its ending rarely occurs at the end of a month; thus it would be necessary to make a special compilation in order to fix the definite limits of the duration of droughts. This has not been done, and to do it now for previous droughts is prohibitive on account of the labor involved.

The object of the present compilation was therefore to ascertain to what extent the calendar-year record of precipitation would serve to accurately fix the times and places of drought in the United States. In the beginning of the study the individual records of stations within a State using both the monthly and annual amounts were used. As the work progressed the difficulties of distinguishing the beginning and the ending of drought even from the monthly totals of precipitation led to its abandonment and the substitution of a shorter method based on the averages of precipitation for each year

for each of the 42 districts organized into what were formerly known as State weather services, now known as climatological sections, of which as a rule there is one in operation for each State or combination of States, except that the six New England States are organized under the name "New England," and Delaware and the District of Columbia are combined with Maryland. The list of sections with the term of years covered by each section is given in Tables 1 and 2.

In some of the sections the record goes back to the early eighties and in others it does not begin until about 1900, so that the early part of the period is not as fully covered as that part subsequent to 1900. The size of the respective sections varies greatly—say, from about 15,000 square miles in the smallest to 265,896 in the largest. The network of climatological stations is somewhat closer east of the Mississippi than to the westward, especially in Rocky Mountain and Plateau States.

The plan followed was to take out for each State the least annual precipitation that had been recorded during the forty-odd years during the life of the record, then the next lowest annual amount, and so on, on an ascending scale until the tenth year on that scale had been reached. Thus it has been practicable to construct for each State a diagram beginning at the low point and increasing to, say, about 90 per cent of the annual average precipitation. In like manner the year of greatest annual precipitation has been taken out and the nine subsequent years when the next greatest annual amount was received, and so on until the tenth year, on a decreasing scale, had been reached.

Tables 1 and 2 include the tabulation above described, the annual amounts of precipitation being expressed as a percentage of the mean annual or, in other words, the normal for the State.

In Table 1 the scale is an increasing one and in Table 2 a decreasing one.

¹ The substance of this article was presented before the May, 1931, meeting of the American Meteorological Society in Washington, D. C.

TABLE 1.—Years of deficient precipitation in the United States—Percentage of actual precipitation expressed in percentages of the normal

States	State means (inches)	Period covered	1		2		3		4		5		6		7		8		9		10	
			Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent
Alabama.....	52.4	1884-1930	1904	75	1889	83	1914	86	1921	87	1895	87	1910	87	1930	88	1924	91	1897	91	1894	91
Arizona.....	13.8	1897-1930	1900	60	1889	61	1924	64	1910	66	1925	72	1904	72	1903	72	1902	76	1901	77	1929	82
Arkansas.....	47.7	1891-1930	1901	75	1924	78	1896	80	1917	85	1899	88	1925	89	1916	89	1914	90	1904	91	1909	92
California.....	25.1	1897-1930	1898	42	1923	57	1929	61	1917	66	1910	67	1924	69	1930	72	1928	75	1908	75	1897	77
Colorado.....	16.8	1888-1930	1888	72	1890	72	1893	78	1889	83	1924	84	1903	84	1902	84	1901	86	1900	87	1894	87
Florida.....	52.5	1892-1930	1927	78	1917	79	1921	87	1895	88	1916	88	1911	90	1913	92	1892	92	1904	92	1898	93
Georgia.....	49.6	1892-1930	1904	75	1893	82	1927	83	1921	83	1910	88	1916	88	1899	89	1896	91	1914	92	1930	93
Idaho.....	17.1	1898-1930	1924	74	1929	78	1928	81	1898	83	1904	87	1901	91	1922	91	1905	92	1900	95	1914	95
Illinois.....	36.4	1878-1930	1901	71	1930	77	1894	80	1914	82	1895	88	1910	88	1879	90	1917	90	1920	91	1925	90
Indiana.....	39.3	1887-1930	1930	76	1901	79	1895	79	1914	80	1894	82	1908	88	1925	89	1899	90	1889	92	1887	93
Iowa.....	31.8	1873-1930	1910	63	1894	69	1901	78	1886	78	1889	79	1930	84	1887	84	1895	85	1897	85	1917	88
Kansas.....	26.8	1887-1930	1917	74	1910	74	1893	75	1894	77	1890	80	1901	80	1913	86	1914	85	1916	90	1921	90
Kentucky.....	45.1	1889-1930	1930	63	1894	77	1904	79	1901	79	1889	81	1895	81	1925	91	1925	91	1903	91	1914	93
Louisiana.....	55.3	1891-1930	1924	70	1917	72	1899	77	1904	80	1902	84	1896	85	1921	87	1906	88	1910	89	1903	91
Maryland and Delaware.....	41.5	1895-1930	1930	56	1895	83	1925	85	1914	87	1904	88	1900	88	1896	89	1910	91	1909	91	1921	92
Michigan.....	30.5	1888-1930	1930	75	1925	84	1910	84	1889	89	1917	90	1895	93	1894	93	1901	93	1899	94	1923	95
Minnesota.....	26.7	1886-1930	1910	57	1889	74	1923	78	1929	81	1917	85	1894	84	1912	88	1930	88	1921	90	1887	93
Mississippi.....	53.2	1888-1930	1889	72	1924	75	1904	79	1896	82	1899	85	1914	88	1930	89	1910	89	1894	90	1895	91
Missouri.....	40.5	1888-1930	1901	62	1930	77	1894	82	1914	86	1890	88	1910	92	1899	93	1906	93	1918	93	1913	94
Montana.....	15.4	1895-1930	1904	73	1919	73	1930	80	1895	86	1928	86	1929	86	1900	88	1924	89	1926	91	1918	91
Nebraska.....	23.5	1876-1930	1894	58	1893	72	1890	74	1910	74	1895	80	1916	81	1899	83	1922	87	1907	87	1898	89
Nevada.....	8.2	1890-1930	1928	60	1924	69	1910	69	1929	71	1926	80	1898	81	1917	82	1903	87	1919	87	1902	88
New England.....	41.9	1888-1930	1930	83	1914	84	1910	85	1924	85	1908	85	1894	87	1905	89	1921	89	1911	94	1892	94
New Jersey.....	46.2	1885-1930	1930	78	1895	81	1918	81	1885	83	1916	83	1921	83	1914	86	1910	86	1923	88	1917	89
New Mexico.....	14.9	1892-1930	1910	64	1917	64	1892	64	1902	63	1894	72	1924	72	1922	74	1899	74	1903	74	1893	84
New York.....	39.4	1890-1930	1930	82	1908	85	1895	86	1899	88	1921	91	1923	91	1909	92	1911	93	1914	93	1910	95
North Carolina.....	50.1	1887-1930	1925	75	1930	77	1911	86	1921	86	1904	87	1926	87	1902	90	1923	90	1897	93	1890	94
North Dakota.....	17.9	1892-1930	1917	61	1910	69	1929	80	1907	82	1930	83	1913	83	1898	85	1920	87	1894	88	1893	89
Ohio.....	38.2	1883-1930	1930	71	1895	75	1894	79	1901	86	1900	87	1889	87	1887	88	1925	90	1899	91	1928	92
Oklahoma.....	32.5	1893-1930	1910	60	1917	69	1901	71	1896	73	1893	80	1894	80	1914	80	1909	84	1924	87	1925	88
Oregon.....	30.6	1890-1930	1910	60	1917	69	1930	71	1901	71	1896	73	1893	79	1894	80	1914	80	1909	84	1922	87
Pennsylvania.....	42.4	1888-1930	1930	68	1895	80	1922	83	1900	83	1909	88	1925	89	1910	92	1923	92	1908	93	1901	95
South Carolina.....	48.3	1887-1930	1925	74	1911	82	1930	84	1904	86	1927	87	1914	91	1887	91	1917	91	1916	92	1903	92
South Dakota.....	20.8	1890-1930	1894	75	1910	75	1925	77	1895	77	1890	79	1898	79	1917	81	1926	80	1893	87	1930	88
Tennessee.....	50.1	1884-1930	1930	80	1925	82	1904	82	1894	86	1885	87	1914	89	1885	90	1925	90	1912	94	1897	92
Texas.....	31.1	1891-1930	1917	53	1893	66	1910	70	1901	72	1909	75	1924	76	1916	80	1924	80	1895	80	1910	83
Utah.....	13.5	1892-1930	1900	63	1902	69	1892	72	1901	75	1903	77	1898	80	1924	80	1924	81	1912	92	1900	92
Virginia.....	42.4	1892-1930	1930	59	1925	77	1921	83	1894	85	1904	85	1914	88	1892	89	1918	84	1913	84	1904	87
Washington.....	36.1	1890-1930	1929	66	1922	68	1911	73	1930	76	1924	78	1925	79	1923	82	1918	89	1910	89	1914	92
West Virginia.....	43.2	1891-1930	1930	59	1895	76	1904	78	1894	81	1892	89	1900	88	1892	89	1910	88	1917	89	1925	90
Wisconsin.....	30.6	1891-1930	1910	70	1902	76	1895	77	1930	82	1891	86	1901	86	1923	87	1924	87	1916	88	1903	88
Wyoming.....	14.6	1899-1930	1902	68	1919	72	1900	77	1910	83	1901	83	1921	87	1914	87	1924	87	1916	88	1903	88
Means.....				68		75		78		82		83		85		86		88		89		93
NEW ENGLAND STATIONS																						
New Bedford, Mass.....	46.2	1814-1930	1930	61	1923	68	1919	71	1921	71	1918	71	1846	75	1849	80	1885	81	1856	81	1910	82
Boston, Mass.....	43.7	1818-1930	1822	63	1846	69	1908	70	1905	73	1837	77	1887	77	1923	78	1930	82	1882	82	1819	82
Lowell, Mass.....	41.5	1826-1930	1914	67	1846	67	1910	69	1837	74	1908	75	1930	75	1834	76	1835	79	1894	81	1891	82
Amherst, Mass.....	44.2	1836-1930	1908	70	1924	71	1894	74	1930	74	1864	79	1846	79	1880	81	1843	86	1850	88	1912	88
Providence, R. I.....	44.2	1832-1930	1914	76	1846	70	1835	70	1930	70	1837	72	1909	77	1915	77	1910	77	1916	79	1849	79

TABLE 2.—Years of greater than normal precipitation in the United States arranged by States and expressed in percentage of normal

States	1		2		3		4		5		6		7		8		9		10	
	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent	Year	Per cent
Alabama.....	1929	147	1900	126	1919	124	1920	124	1926	117	1923	117	1922	112	1909	111	1888	110	1892	109
Arizona.....	1905	193	1919	142	1916	124	1923	124	1914	124	1926	121	1906	116	1908	114	1927	114	1915	114
Arkansas.....	1927	138	1905	133	1923	125	1892	121	1906	120	1898	120	1919	115	1920	115	1913	113	1915	112
California.....	1923	127	1909	125	1927	121	1891	120	1906	118	1897	117	1915	117	1921	117	1911	115	1914	115
Colorado.....	1909	169	1906	155	1916	140	1915	136	1907	130	1914	124	1904	122	1911	118	1922	116	1926	108
Florida.....	1912	124	1924	117	1905	117	1900	116	1928	116	1926	115	1929	112	1920	111	1922	110	1919	110
Georgia.....	1929	141	1912	128	1928	121	1920	120	1901	116	1900	116	1922	112	1919	112	1906	112	1924	112
Idaho.....	1927	134	1909	130	1912	127	1906	122	1916	122	1907	120	1917	119	1913	117	1915	113	1925	112
Illinois.....	1927	136	1882	132	1883	130	1898	129	1881	121	1884	119	1909	119	1926	119	1902	116	1915	116
Indiana.....	1890	126	1927	125	1909	123	1929	120	1898	117	1907	114	1913	112	1926	111	1905	110	1923	109
Iowa.....	1881	139	1902	139	1909	127	1915	124	1896	117	1919	117	1876	116	1892	116	1928	113	1884	112
Kansas.....	1915	152	1902	128	1928	125	1927	121	1908	121	1923	121	1898	120	1903	118	1909	117	1891	116
Kentucky.....	1890	130	1923	120	1927	118	1898	116	1919	116	1915	116	1909	114	1910	112	1926	112	1891	110
Louisiana.....	1905	139	1923	129	1919	125	1922	121	1926	119	1904	119	1912	117	1913	117	1929	116	1920	114
Maryland and Delaware.....	1902	119	1907	119	1906	116	1919	115	1903	114	1924	112	1901	109	1928	109	1926	107	1905	106
Michigan.....	1893	114	1911	114	1890	113	1916	112	1892	110	1905	109	1928	109	1926	108	1903	107	1902	107
Minnesota.....	1905	130	1903	129	1906	123	1896	122	1899	118	1900	116	1904	116	1908	116	1902	116	1909	115
Mississippi.....	1923	134	1919	131	1900	125	1912	125	1905	123	1920	119	1929	113	1911	113	1922	112	1909	110
Missouri.....	1927	134	1898	133	1915	122	1929	116	1928	113	1905	113	1909	112	1902	112	1896	111	1921	108
Montana.....	1927	134	1908	132	1909	128	1915	123	1916	123	1911	121	1906	121	1923	119	1896	115	1912	113
Nebraska.....	1915	152	1905	135	1881	132	1883	132	1891	131	1902	124	1903	120	1903	117	1906	115	1908	115
Nevada.....	1906	194	1891	174	1901	161	1907	160	1890	159	1909	136	1913	136	1894	135	1896	131	1904	131
New England.....	1888	134	1898	122	1890	121	1889	118	1920	116	1901	115	1902	112	1897	112	1900	110	1927	110
New Jersey.....	1889	138	1902	128	1903	121	1898	113	1888	113	1919	113	1920	112	1907	112	1901	112	1897	112
New Mexico.....	1919	141	1905	141	1923	131	1914	131	1911	121	1915	119	1926	117	1897	111	1921	111	1929	111
New York.....	1890	126	1927	115	1892	111	1898	111	1903	110	1901	110	1902	109	1929	109	1893	106	1925	106
North Carolina.....	1901	125	1929	124	1906	119	1908	115	1922	114	1920	113	1928	112	1888	110	1891	109	1924	109
North Dakota.....	1896	132	1927	121	1916	116	1912	113	1905	112	1908	112	1906	111	1921	111	1901	109	1915	109
Ohio.....	1890	132	1929	120	1883	119	1913	118	1898	115	1926	115	1921	113	1927	113	1907	113	1909	113
Oklahoma.....	1908	156	1915	140	1923	138	1902	125	1905	123	1927	122	1926	120	1905	112	1928	112	1920	112
Oregon.....	1896	183	1894	166	1893	160	1899	157	1902	151	1904	149	1891	147	1897	143	1895	143	1907	137
Pennsylvania.....	1889	124	1890	121	1902	112	1927	112	1919	111	1903	110	1888	109	1891	108	1898	108	1901	108
South Carolina.....	1929	138	1928	128	1922	121	1924	119	1901	115	1906	114	1888	114	1912	114	1893	111	1908	111
South Dakota.....	1915	142	1906	140	1920	137	1905	133	1908	125	1922	121	1896	119	1909	118	1927	115	1900	114
Tennessee.....	1929	119	1890	115	1923	115	1919	115	1920	113	1884	111	1912	109	1922	109	1926	109	1892	108
Texas.....	1919	147	1900	137	1905	135	1923	129	1914	122	1926	118	1913	117	1920	110	1907	110	1902	110
Utah.....	1909	149	1906	140	1920	127	1927	127	1921	126	1907	123	1916	123	1908	113	1922	113	1897	113
Virginia.....	1902	121	1901	118	1906	117	1924	113	1893	110	1920	109	1929	109	1908	106	1903	106	1922	106
Washington.....	1896	128	1894	120	1891	120	1899	117	1902	117	1927	117	1893	115	1897	110	1900	104	1909	107
West Virginia.....	1907	122	1926	116	1913	113	1927	113	1924	110	1898	110	1919	110	1911	110	1929	107	1891	107
Wisconsin.....	1911	121	1903	117	1905	117	1906	117	1926	116	1892	115	1900	114	1916	111	1919	109	1928	108
Wyoming.....	1915	133	1923	133	1912	127	1927	125	1906	122	1908	120	1909	113	1905	111	1918	111	1913	111
Means.....	189		130		125		122		119		117		116		116		116		113	
New Bedford, Mass, 1814-1929.....	1829	142	1830	141	1827	136	1850	136	1898	136	1890	134	1831	133	1823	130	1868	123	1888	120

The chief interest in the two tables is historic; the data in them will serve as a reference point for future studies of excess or deficit in annual precipitation.

Obviously the percentage of the normal that is received in the dry regions of the Southwest is less than for the humid sections east of the Mississippi; somewhat unexpected results are the relatively low percentage of rain that is received in dry years in California, Oregon, and Washington, the range being from 42 per cent in California to 66 per cent in Washington. In Arizona and parts of New Mexico low percentages were to be expected. Arizona, especially the lowlands of the western portion, occasionally receives in very dry years at individual stations less than 1 per cent of the average annual precipitation. At the higher levels individual stations receive nearly as great a percentage of the annual as do points situated in the humid regions of the East. The percentage of the annual precipitation received by the Rocky Mountain States of Colorado, Idaho, and Montana is greater than was expected. Florida in the South, Indiana and Michigan in the North, and New York and New England in the Northeast show the greatest stability, or in other words less percentage variation than in other places in the humid region. The New England record as given in Table 1 depends on the observations for the period 1888-1930; if, however, the individual stations having from 50 to 100 years of observations be considered smaller percentages will be found to obtain; thus for the driest, second, and third driest the percentages were 66, 69, and 71, respectively. (See records of five individual long-record stations at bottom of Table 1.)

The data of Table 1 establishes the fact that the year 1930 set the record for extreme dryness in the United States as a whole; the States of Maryland and Delaware, the two Virginias, Kentucky, and Ohio standing in the order named with respect to the percentage of the normal precipitation that was received. The drought of 1901 in Missouri, those of 1910 in Iowa, 1917 in North Dakota, Texas, and possibly other parts of the country, were more intense, precipitation being considered, than in 1930.

Following is a comparison of the average percentage of the normal precipitation in all recorded droughts as shown at the bottom of Table 1 with that of England and Wales in the five driest years in Great Britain.¹

	Per cent
United States, average of all droughts.....	68
England and Wales, drought of—	
1921.....	71
1887.....	74
1854.....	77
1864.....	78
1870.....	82

It is of additional interest to observe that while drought in the United States is not always synchronous with drought in the British Isles it is more so than would be required by chance. The year of greatest drought in Britain—1921—was also a warm and droughty year in the United States, the second greatest drought in Britain—1887—was droughty in some sections but was not so severe and general as in 1886, the year previous; 1854-55 and 1856-57 were all more or less droughty years in this country, but the droughts were local in character rather than general and this is also the case in the early seventies.

As has been found in earlier studies of the precipitation in the United States² the fact that the smaller the average rainfall the greater is the variation from year to year is

again confirmed; for this and other reasons the actual precipitation in Tables 1 and 2 is given as a percentage of the normal for the section. There are several more or less distinct groups of rainfall distribution in the United States; following is a rather coarse grouping:

1. The Pacific coast and Plateau States, embracing Washington, Oregon, California, Nevada, Utah, Arizona, and New Mexico. This group is characterized by the greatest annual variation in precipitation to be found in continental United States.

2. The Plains States of North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, Missouri, Iowa, and Minnesota. The three last named while not strictly Great Plains States may be included in that group because of similar rainfall distribution. They form the largest group and are characterized by what may be called the continental type of rainfall distribution.

3. The Gulf States of Louisiana, Mississippi, Alabama, and Florida. This group receives a greater precipitation than either of the two first mentioned and the annual rainfall may be said to be much more dependable; that is, it varies less from the normal.

4. Finally the group of Northeastern States have the most dependable precipitation of any part of the United States. I include in this group New England, New York, New Jersey, Pennsylvania, and Michigan.

In Table 3 will be found a summary showing the percentage of the annual precipitation for the driest year, the second and third driest on the average of each group. Likewise the average percentage of the greatest, the second, and third greatest is also shown.

TABLE 3.—Percentage of the average precipitation in the three years of deficient and the three years of greatest precipitation in the groups of States numbered 1 to 4 on the left of the table

Groups	Least			Greatest			Range
	1	2	3	1	2	3	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
No. 1.....	59	65	67	167	149	136	108
No. 2.....	94	72	77	143	133	129	79
No. 3.....	74	77	82	136	126	123	62
No. 4.....	78	83	84	127	120	116	49

The sequence of dry years, Figure 1.—The data of Table No. 1 have been summarized and reproduced as Figure 1, in order to show graphically the sequence and grouping of the dry years; column 1 of that figure shows, as previously explained the number of sections, if any, in which the least annual precipitation of the whole series of years was recorded; column 2 the number in which the next to the least was recorded; and so on, so that the series of steps to the right of column 1 may be considered as a series of annual precipitation amounts which approach but do not reach the normal.

The full lines in the figure show those years that may be considered as falling within the group of major dry years. These are 1889, 1894, 1901, 1910, 1917, 1921, 1924, and 1930. There is a slight tendency in the groups to spread fan shaped toward the right, thus indicating that the peak dry year is preceded in most cases by gradually diminishing precipitation during one or two years prior to that year, thus the peak dry year of 1894 was preceded by diminishing precipitation in 1892 and 1893 and was followed by somewhat dry years in 1896-97. This is merely another way of saying that severe droughts gradually approach a peak year and that the return of normal conditions is brought about gradually.

¹ Quart. Jour. Roy. Met. Soc. 48: 140.

² Henry, Alfred J. Rainfall of the United States, Weather Bureau Bulletin D, Washington, 1897.

DRY YEARS - SCALE 1 TO 10

	1	2	3	4	5	6	7	8	9	10	Total
1879							1				1
85				1			1				2
86				1							1
87							3	1		2	6
88	1										1
89	1	3		2	2	1			2		11
90		1	1		3					1	6
91					1						1
92			2		1		1	1		1	6
93		3	2		1	1			1	3	11
94	2	2	3	4	2	3	2	1	2	2	23
95		5	3	3	3	2	1	2		1	20
96			1	2	2	1	1	1			8
97									3	2	5
98	1			1		3	1			2	8
99			1	1	2		3	2	2		11
1900	2		1	1	1	2	1		3		11
1	3	1	2	5	1	3		2	1		18
2	1	2		1	1		2	1		1	9
3					1	1	1	1	2	2	8
4	3		4	2	4	1			2	2	18
5							1	1			2
6								2			2
7				1					1		2
8		1			1	1			2	1	6
9					2		1	1	2	2	8
10	6	3	4	3	2	3	1	4	1	2	29
11		1	2			1		1	1		6
12							1	1	1		3
13						1	2		1	1	5
14		1	1	4		4	3	3	3	2	21
16					2	2	2		3	1	10
17	3	5		2	2		2	2	1	2	19
18			1				1	1	1	1	5
19		2							1		3
20								1	1		2
21			2	3	1	2	1	1	1	2	13
22		1	1				2	1		1	6
23		1	1			1	2	2	1	1	9
24	2	3	1	1	2	3	1	3	1		17
25	2	3	2			3	1	3		3	17
26					1	1		1	1		4
27	1		1		1						3
28	1		1		2			1	1	1	7
29	1	1	2	2		1				1	8
30	12	3	3	2	1	1	3	1		2	28
Sums	42	42	42	42	42	42	42	42	42	42	420

FIGURE 1.—Chronological list of years with deficient precipitation on a scale of 1 to 10.
(See text)

WET YEARS - SCALE 1 TO 10

	1	2	3	4	5	6	7	8	9	10	Total
1876							1				1
81	1		1		1						3
82		1									1
83			2	1							3
84						2				1	3
88	1				1		2	1	1		6
89	2			1							3
90	4	2	2		1						9
91		1	1	1	1		1	1	1	3	10
92			1	1	1	2		1	1	2	9
93	1		1		1		1				4
94		2	-					1	1		4
96	3			1	1		1				6
97						1		4	4	2	11
98		2		4	2	2	1				11
99				2	1						3
1900		2	1	1		3	1			1	9
1	1	1	1		2	2	1			1	9
2	2	3	1	1	2	1	2	1	1	2	16
3		2	1		2	1		2	2		10
4						1	2			1	4
5	3	3	3	1	3	2		2	2	1	20
6	1	3	4	2	3	1	3				17
7	1	1		1	1	3		1	1	1	10
8	1	1		1	2	2		4	4	2	17
9	2	2	3			1	4	2	2	4	20
10								1	1		2
11	1	1			1	1		3	3		10
12	1	1	2	2			2	1	1	1	11
13			1	1			3	2	2	1	10
14				1	2	1				1	5
15	4	1	1	3		2	1			4	16
16			3	1	2		1	1	1		9
17							1				1
19	2	2	2	2	2	2	2	1	1	1	17
20			2	2	2	3	1	3	3	2	18
21					1		1	2	2	1	7
22			1	1	1		2	1	1	1	8
23	2	3	4	2		2	1	1	1	1	17
24		1		2	1	1				2	7
25										2	2
26		1			3	4	2	3	3	1	17
27	5	3	2	5		2		1	1	1	20
28		1	2		2		2	1	1	1	10
29	4	2		2			3	1	1	1	14
30											0
Sums	42	42	42	42	42	42	42	42	42	42	420

FIGURE 2.—Chronological list of years with greater than the normal precipitation.
(See text)

The dry year 1910 is seemingly in a class by itself, as is also 1917. The onset of the first named was quite sudden as compared with the others shown in the figure. The year 1917 was one of maximum spottedness of the sun and that fact has been used by some in an effort to tie up the occurrence of droughts with the occurrence of many sun spots; the difficulty that must be faced by them is that the record shows that droughts occur almost simultaneously with both increasing and diminishing sun-spot numbers. (See Table 4.)

TABLE 4.—Droughts in the United States and sun spots

Year	Sun-spot curve		Smoothed sun-spot numbers			Nearest epoch of—	
	Rising	Falling	January	December	Year	Minimum	Maximum
1854		F	28.2	15.6	21.0	1856.0	
1856	R		3.3	9.3	5.2	1856.0	
1857	R		10.5	36.0	23.0	1856.0	
1860		F	97.2	90.6	94.8		1860.1
1863		F	51.9	43.2	45.4		1860.1
1864	R ¹	F	44.8	41.3	45.2	1867.2	
1870	R		110.0	135.4	131.8		1870.6
1881	R		47.0	62.4	54.4	1873.9	
1893	R		78.0	86.7	83.7		1894.1
1894		F	87.9	71.3	79.1		1894.1
1895		F	67.7	52.5	61.5		1894.1
1901		F	4.8	2.8	3.4	1901.7	
1910		F ²	31.5	12.8	21.0	1913.6	
1916	R		57.8	68.7	59.1		1917.6
1917	R		73.4	98.3	95.2		1917.6
1924	R		0.5	16.5	16.7	1923.6	
1930		F	63.7	23.0			1928.0

¹ Rising followed by falling.

² The driest year in the United States in forty-odd years.

The 1924-25 drought had its beginning in 1921 and was distinguishable as late as 1926, although in that year a number of States had more than the average precipitation. It happens, not infrequently, that one and the same year may yield abundant rain in one part of the country and withhold it in another, as illustrated by 1927, the year of the great Mississippi flood. In that year Florida, Georgia, and South Carolina suffered more or less from drought.

YEARS OF GREATEST PRECIPITATION

The chronological record of years with greater than the normal precipitation as summarized from the data of Table 2 is presented in Figure 2. In that figure I have indicated the probable grouping of years of greater than the normal precipitation by inclosing them in continuous lines. These years occur also in groups as in the case of years of deficient rainfall. The groups are

centered about 1890, 1898, 1902, 1905, 1909, 1912, 1915, 1919, 1923, and finally in 1927, 1928, and 1929.

The average interval between these dates is roughly four years.

If the figures of the extreme right-hand column of Tables 3 and 4 be smoothed by the formula $\left(\frac{a+2b+c}{4}\right)$ and the smoothed values be plotted against time as abscissa the resulting curve indicates a period of approximately four years between epochs of maximum and minimum. I attach no great importance to these curves, since the smoothing process distorts or rather displaces the epochs of maximum and minimum and reduces the amplitude of the oscillations.

Figure 2 is complementary to Figure 1, since it presents the grouping of the opposite extreme in the annual precipitation. Viewing the two figures one must be struck with the apparent absence of chance in the annual distribution of precipitation; rather these two figures favor the idea that the years of little and much rainfall succeed each other in a wave like sort of motion which advance from west to east and perhaps in due course encircle the globe. It is also possible to identify in them the well-known Brückner years of dry and wet weather said to repeat themselves in a period of 35 years.

Another outstanding feature to which attention is invited is that years of drought do not come suddenly and unheralded but almost uniformly preceded by one or two years of diminished precipitation in various parts of the United States; likewise peak dry years are sometimes followed immediately by one or two years of fairly good rains apparently intercalated in a series of dry years as in 1902-03 and again in 1915-16.

Conclusions.—The facts hereinbefore presented lead to the belief that in the great majority of cases the total annual precipitation may be used as a criterion on drought; it must, however, be used intelligently, bearing in mind that the area under consideration with up to 70 per cent of its annual normal rainfall may have been very dry in spots but as whole the deficit may not have been equally pronounced.

In the Pacific coast and Plateau States any one year with but 60 per cent of its annual precipitation may be classed as a dry year. In the Great Plains States, excepting South Dakota, 65 per cent, while not as low as has been reached in past droughts may be accepted as a measure of severe drought. In the Gulf States the range is from 70 to 75 per cent and in the Northeastern States the lower limit is from 75 to 85 per cent.

SOLAR RADIATION INTENSITIES WITHIN THE ARCTIC CIRCLE

By HERBERT H. KIMBALL

(Weather Bureau, Washington, D. C., April 15, 1931)

In summaries of solar radiation measurements prepared by the author,¹ the following stations within, or practically on the Arctic Circle have been listed:

Abisko, Sweden, latitude 68° 21' N., longitude 18° 49' E., altitude 390 meters.

Jokkmokk, Sweden, latitude 66° 36' N., longitude 19° 51' E., altitude 255 meters.

Mount Evans, Greenland, latitude 66° 51' N., longitude 50° 50' W., altitude 394 meters.

Rovaniemi, Finland, latitude 66° 29' N., longitude 25° 44' E., altitude 200 meters.

Treurenberg, Spitzbergen, latitude 79° 55' N., longitude 16° 52' E., altitude 9 meters.

At these stations solar radiation intensity at normal incidence was measured. Now we may add to the above list Green Harbor, Spitzbergen, latitude 78° 00' N., longitude 14° 05' E., with continuous measurements of the total solar radiation (direct + diffuse) received on a horizontal surface.

SOLAR RADIATION MEASUREMENTS AT GREEN HARBOR, SPITZBERGEN

At the second general assembly of the International Geodetic and Geophysical Union at Madrid, in 1924, the

¹ Measurements of solar radiation intensity and determinations of its depletion by the atmosphere. MONTHLY WEATHER REVIEW, 55: 155, April, 1927; 58: 43, February, 1930.